

VISION CALIFORNIA | CHARTING OUR FUTURE

STATEWIDE SCENARIOS REPORT



This report accompanies the California High Speed Rail Authority's public release of the Vision California *Rapid Fire* modeling tool and a set of state-wide scenarios that measure the impact of varying land use patterns, transportation investments, and policy directions on greenhouse gas emissions, air pollution, water and energy use, land consumption, and infrastructure cost. It provides brief background material on the Vision California project, and describes the *Rapid Fire* model, scenarios, and results. A detailed description of the *Rapid Fire* model can be found in the *Rapid Fire Model White Paper and Technical Guide*¹. More detailed information about the Vision California project can be found at visioncalifornia.org and at www.calthorpe.com/vision-california.

Vision California and Policy Context

Vision California is an unprecedented effort to explore the role of land use and transportation investments in meeting the environmental, fiscal, and public health challenges facing California over the coming decades. Funded by the California High Speed Rail Authority (cahighspeedrail.ca.gov) in partnership with the California Strategic Growth Council (www.sgc.ca.gov), the project is producing new scenario development and analysis tools to compare physical growth alternatives. By clearly expressing the consequences of different scenarios, Vision California can inform the policy and programmatic decisions that will drive California's infrastructure investments. The project's tools and results can be used to impact critical state and regional policy decisions, and to inform and sync with improvements to regional (MPO) travel models.

Vision California will:

- Highlight the unique opportunity presented by California's planned High Speed Rail network in shaping growth and other investments.

- Frame California's development issues in a comprehensive manner, illustrating the role of land use in meeting greenhouse gas (GHG) reduction targets through robust analysis.
- Illustrate the connections between land use and other major challenges, including water and energy use, housing affordability, public health, farmland preservation, infrastructure provision, and economic development.
- Clearly link land use and infrastructure priorities to mandated targets as set forth by AB 32, SB 375, and the California Air Resources Board (CARB).
- Produce scalable tools, for use by state agencies, regions, local governments, and the non-profit community, which can defensibly measure the impacts of land use and transportation investment scenarios.
- Build upon Blueprints and other regional plans to produce statewide growth scenarios that go beyond regional boundaries and assess the combined impact of these plans.
- Connect state and national goals for energy independence, energy efficiency, and green job creation to land use and transportation investments.

Vision California is driven in part by the challenges set forth by the 2006 passage of the California Global Warming Solutions Act (AB 32), which sets aggressive targets for the reduction of greenhouse gas emissions (GHGs). The project is designed to provide critical context for the implementation of Senate Bill 375 (SB 375) and land use-related GHG-reduction targets for local governments, as it will illustrate and comprehensively measure the role of land use and SB 375-mandated regional "Sustainable Communities Strategies" in meeting AB 32 GHG targets.

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CALIFORNIA
HIGH-SPEED RAIL
AUTHORITY



CHHS
California Health & Human Services Agency



California
Environmental
Protection Agency

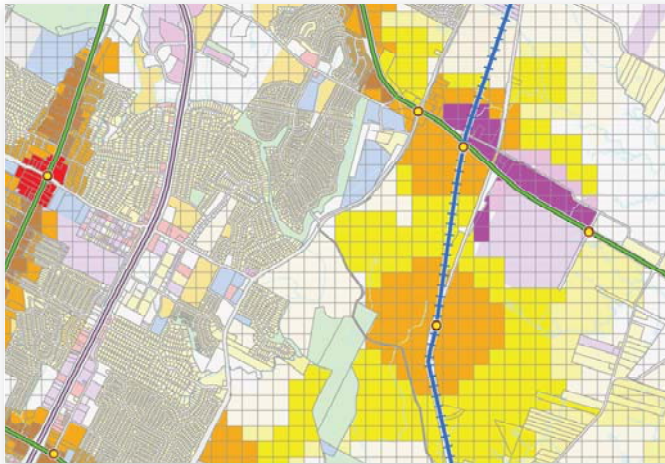
CALTHORPE ASSOCIATES
URBAN DESIGNERS, PLANNERS, ARCHITECTS

OVERVIEW of VISION CALIFORNIA MODELING TOOLS

Vision California includes the development of two distinct yet complementary modeling tools: the 'Urban Footprint' map-based model and the *Rapid Fire* spreadsheet-based tool.

The Urban Footprint Map-Based Model

The *Urban Footprint* map-based model, currently under development, uses geographic information system (GIS) technology to create and evaluate physical land use-transportation investment scenarios. Scenarios are defined through the application of 'Place Types' to the environment. The model's suite of Place Types represents a complete range of development types and patterns, from higher density mixed-use centers, to separated-use residential and commercial areas, to institutional and industrial areas. The physical and demographic characteristics associated with the Place Types are used to calculate the impacts of each scenario. Output metrics will include: land consumption; infrastructure cost (capital as well as operations & maintenance); building energy and water consumption, cost, and associated CO₂ emissions; public health impacts; vehicle miles traveled and all related fuel, GHG, and pollutant emissions; and non-auto travel mode share and other related travel metrics.



The Rapid Fire Model

The *Rapid Fire* model is a user-friendly spreadsheet-based tool which produces and evaluates high-level statewide and/or regional scenarios. It allows for efficient, iterative, and transparent testing of different combinations of compact, urban, and more sprawling growth for a wide variety of metrics including VMT; greenhouse gas emissions from cars and buildings; air pollution; fuel use and cost; building energy and water use and cost; land consumption; and infrastructure cost. The *Rapid Fire* tool can run on virtually all desktop and laptop computers, and is designed so that all assumptions are clear, transparent, and can be easily modified or customized. See inset for more information.

The Rapid Fire Modeling Framework

The *Rapid Fire* model emerged out of the near-term need for a comprehensive modeling tool that could inform state and regional agencies and policy makers in evaluating climate, land use, and infrastructure investment policies. The model calculates results based on empirical data and the latest research on the role of land use and transportation systems on automobile travel; emissions; and land, energy, and water consumption. It provides a single transparent framework within which these assumptions and research can be loaded to test the impacts of varying land use patterns on environmental and fiscal performance. The transparency of the model's framework of input assumptions makes it readily adaptable to different study areas, as well as responsive to data emerging from ongoing technical analyses by state and regional agencies.

The model allows users to create scenarios at national, statewide, or regional scales and produces results for a range of metrics including:

- GHG (CO₂e) emissions from cars and buildings
- Air pollution
- Fuel use and cost
- Building energy and water use, and cost
- Land consumption
- Infrastructure cost

The model summarizes results such that users can easily compare the impacts of different scenarios. All assumptions are clearly identified and can be easily modified.

The *Rapid Fire* model is not meant to replace more complex travel models or map-based models. Rather, it is designed to fill a timely need for defensible comparative analysis that can inform land use and climate policy development and provide a credible and flexible sounding board for state and regional entities as they review and analyze plans and policies. A detailed description of the Vision California *Rapid Fire* model can be found in the *Rapid Fire Model White Paper and Technical Guide*.

CALIFORNIA *RAPID FIRE* SCENARIOS and MODEL RESULTS

Combining Land Use and Policy Options

The Rapid Fire model was used to analyze a set of statewide growth scenarios. Each scenario pairs one of three distinct land use options with one of two policy packages. The land use options vary the patterns of new growth, while the policy packages vary standards for automobile technology and fuel composition, building energy and water efficiency, and energy generation. The scenarios highlight the impacts of land use on GHG emissions and other critical metrics, as well as the combined impacts of land use and

policy, which are vital to discussions as California reaches towards aggressive climate, energy, water, and fiscal efficiency targets.

Each scenario accommodates the same amount of projected population and job growth to the years 2020, 2035, and 2050. By 2050, the state’s population is expected to grow to 59.5 million people and 24 million jobs. This report compares the four distinct scenarios described below. The land use and policy components are described in greater detail on the following pages.

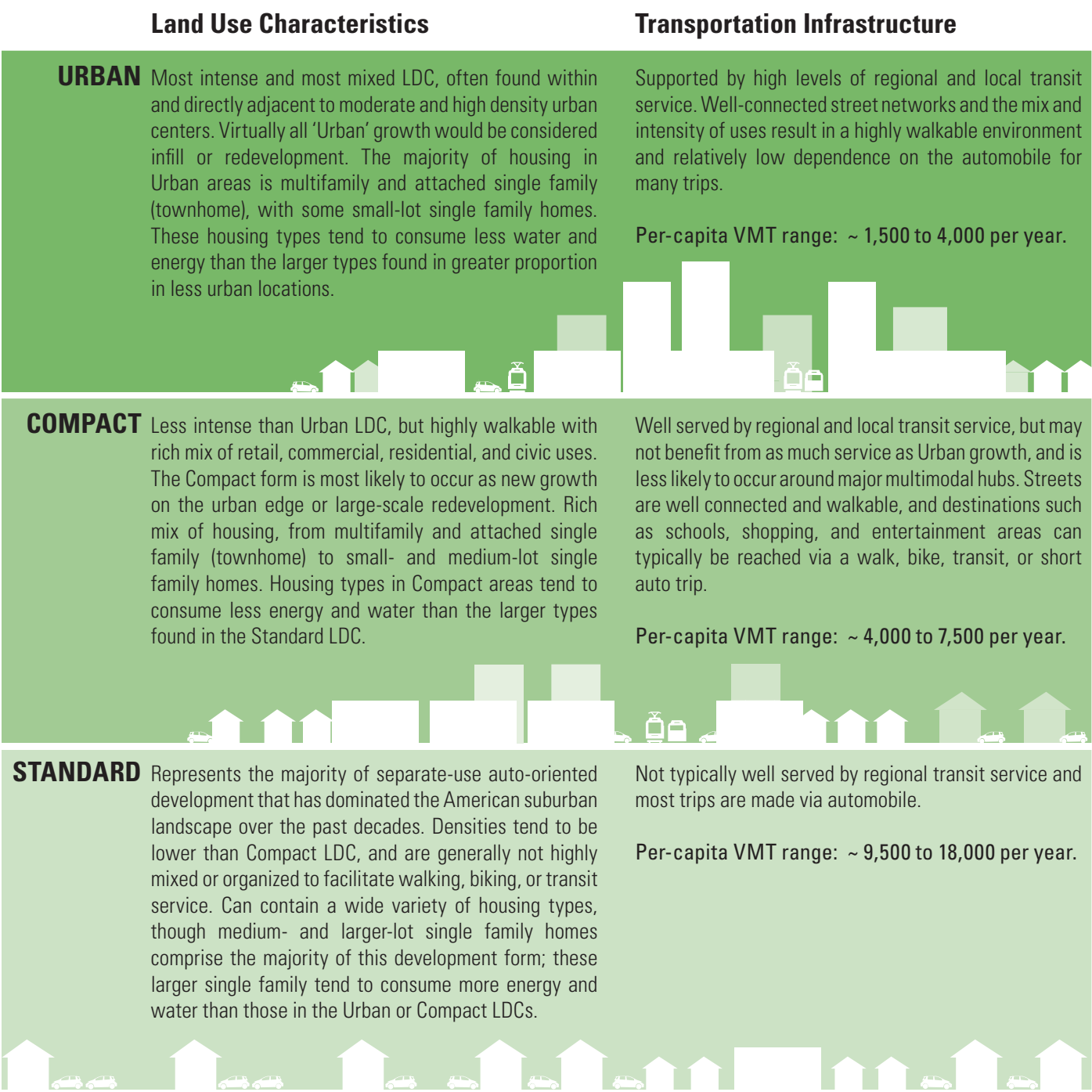
		POLICY OPTIONS	
		TREND	GREEN
LAND USE OPTIONS	TREND	<div><div>A1</div><div>TREND POLICY / TREND GROWTH</div><div>"BUSINESS AS USUAL"</div><div>This scenario combines the trend land use patterns of past decades with a very moderate set of trend-based policies for auto and fuel technology, building energy and water efficiency, and energy generation. It serves as an important comparison to other scenarios in which land use and policy trends undergo more significant change.</div></div>	
	MIXED	<div><div>B1</div><div>TREND POLICY / MIXED GROWTH</div><div>"MIXED GROWTH"</div><div>This scenario tests a future in which roughly half of new growth is accommodated in compact and urban forms. This land use pattern is combined with the "Trend" policy set.</div></div>	
	SMART	<div><div>C1</div><div>TREND POLICY / SMART GROWTH</div><div>"GROWING SMART"</div><div>In this scenario, the state sees an increasing proportion of urban infill and compact growth. This land use pattern is combined with the same trend-based policy set as for the Business as Usual scenario.</div></div>	<div><div>C2</div><div>GREEN POLICY / SMART GROWTH</div><div>"GREEN FUTURE"</div><div>In this scenario, the state sees an increasing proportion of urban infill and compact growth. This land use pattern is combined with a "Green" policy set that reflects the relatively ambitious direction of state policies that have already been adopted, or are under consideration by the CA Air Resources Board, CA Energy Commission, CA Public Utilities Commission, and other state agencies.</div></div>

LAND USE OPTIONS

The Vision California Rapid Fire scenarios include one of three distinct land use options: Trend, Mixed Growth, or Smart Growth. Each of these options is defined by the proportion of growth allocated to Urban, Compact, and Standard Land Development Categories (LDCs). The LDCs represent distinct forms of land use,

ranging from dense, walkable, mixed-use urban areas that are well served by transit, to lower-intensity, less walkable places where land uses are segregated and most trips are made via automobile. They are described generally below.

Land Development Categories



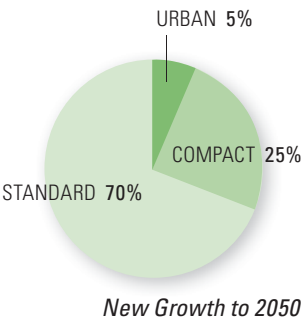
THREE LAND USE OPTIONS

The Rapid Fire land use options are defined according to their proportions of the three Land Development Categories. All options accommodate the same amounts of housing unit and job growth. The pie charts below show the composition of growth in each land use option by 2050, which in turn result in different housing type mixes. The housing type mix for new growth in each option is shown in the upper bar charts. The total end-state housing type mix in 2050 –new development plus the existing housing stock – is shown in the lower charts.

Land Use Option A. Trend Growth

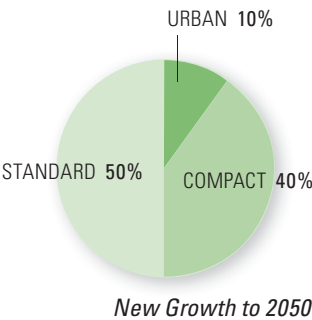
The Trend Growth option represents a future based on historic market trends, development patterns, and transportation investments in California.^{2, 3, 4} This option is comprised of 70% Standard development, with Compact and Urban development totaling 30%. The resulting housing type mix aligns with historic market trends in California, in which single family detached homes have comprised the majority of new construction in major metropolitan areas.⁵

LDC Proportions



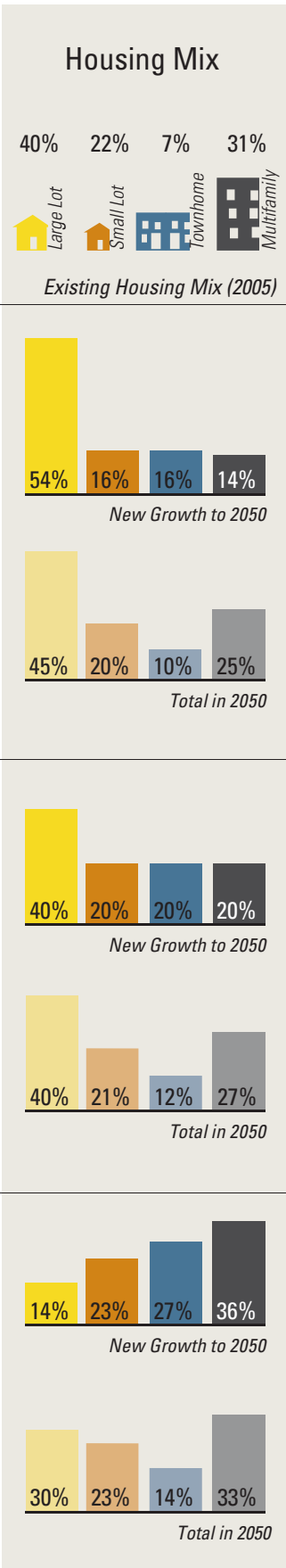
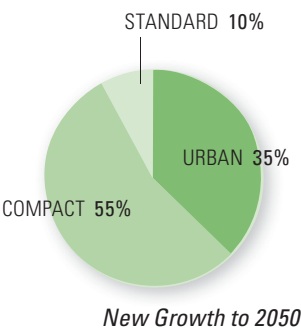
Land Use Option B. Mixed Growth

The Mixed Growth option reflects the least-aggressive end of projected market and development trends, which indicate that 50-70% of development in California between 2010 and 2020 should be Compact or Urban. These trends stem from changing demographics and lifestyles, trends in construction, the undersupply of compact units on the market, and projected energy price increases. The Mixed Growth option accommodates 50% of growth in Compact or Urban forms. It is assumed that growth will be supported by transportation investments that balance roadway and transit infrastructure, and a move towards planning for compact development by regions and cities.



Land Use Option C. Smart Growth

The Smart Growth option assumes that a greater share of new growth will occur in Urban and Compact forms to meet a current and projected undersupply of compact development and align with projected demographic, regulatory, and market trends.⁶ This option accommodates 55% of new growth in Compact and 35% in Urban forms by 2050. Despite these high proportions, the 2050 end-state housing mix of the Smart Growth option tracks the current (2005) housing mix, with nearly 70% of housing in single family detached or attached (townhome) types. It is assumed that significant investments in transit and other infrastructure will be made to support smart growth.



CHANGING HOUSING PREFERENCES and DEMAND

The proportion of housing types in the Mixed Growth and Smart Growth land use options are supported by real estate market analysis that indicates that demand is moving away from larger single-family detached homes toward smaller detached or attached housing units.⁷ Affordability, accessibility, and demographics are key factors behind this change. Nationally, market analysts predict that apartment and townhouse living near transit will drive much housing demand going forward.⁸ Lifestyle preferences also play a role: a survey of Atlanta households found that 40% of those living in single family detached neighborhoods would trade large lots for smaller ones with more community-friendly amenities, including sidewalks, narrower streets, shops and services, and parks.⁹

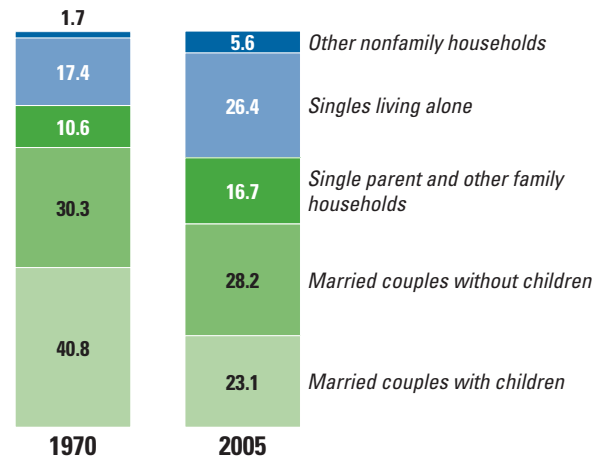
Changes in housing preference are also grounded in demographic changes. Married couples with children, the primary market for single-family detached homes, now account for only 23% of all households nationwide, a proportion that continues to shrink each year.¹⁰ By contrast, the proportion of singles, single parents, empty nesters, and seniors – who generally prefer more compact single family and multifamily housing types¹¹ – has grown steadily.

Further analysis indicates an ongoing disconnect between housing type supply and demand; despite demographic trends and expressed preferences, single family homes accounted for the majority of new construction over the last decade. A 2006 study by Arthur Nelson finds that “the market demand for new homes through 2025 may be almost exclusively for attached and small-lot units.”¹² As summarized in the table at lower right, Nelson estimates a national *oversupply* of one million large-lot single family units to 2025 – that is, there are already more large-lot units existing today than will be needed by 2025. By contrast, demand for small-lot single family and attached units is very high.

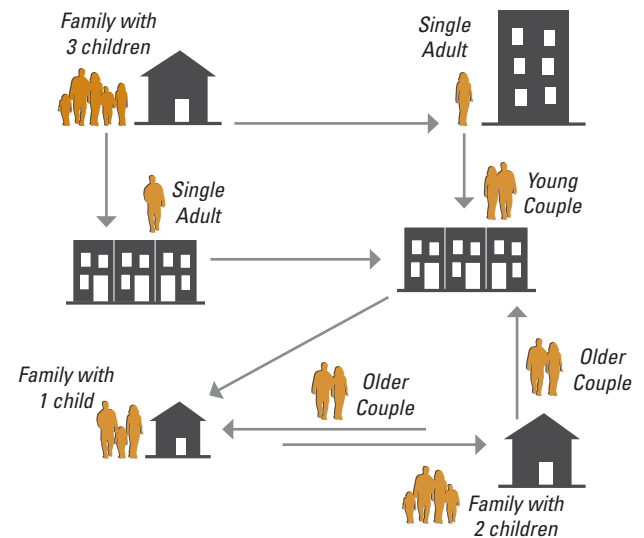
For numerous reasons, including affordability, accessibility, and quality of life issues, housing preferences are changing. A recent EPA study finds that in the years since 2005, while overall residential construction has declined sharply, construction of new high-density residential units has not declined from the 200,000-unit-per-year rate of production seen at the height of the real estate boom in 2005. Similarly, construction of multifamily rental units has increased slightly through 2008; and in many regions across the country, there has been a dramatic increase in the share of new construction built in central cities and older suburbs, as opposed to at the urban fringe.¹³ The oversaturation of larger single-family homes in the market has been underscored by the recent foreclosure crisis: in California, the homes most susceptible to foreclosure have been detached single-family homes located in suburban development patterns.¹⁴ By contrast, the homes that have weathered the crisis and continue to be in demand tend to be located in compact communities.¹⁵ The related trends of changing household demographics and growing preference for compact housing types have informed the housing unit mix composition of the Rapid Fire scenarios.

Change in U.S. household demographics, 1970-2005

Source: US Census Bureau, 2005



The Housing Life Cycle



Projected National Housing Demand to 2025 by Unit Type

Source: Nelson, 2006

Unit Type	Existing Units (2003)	Demand (2025)	Net New Units Needed by 2025
Attached	27,000,000	44,000,000	17,000,000
Small Lot ¹⁶	22,000,000	40,000,000	18,000,000
Large Lot ¹⁷	57,000,000	56,000,000	- 1,000,000

POLICY PACKAGES

The Rapid Fire policy packages represent different levels of improvement in automobile and fuel technology, building energy and water efficiency, and energy generation. For comparison, a business-as-usual approach is contrasted with a more aggressive set of policies that reflects the current direction of state agencies as they address the regulatory framework required to meet climate, energy, water, and fiscal challenges. The policy package assumptions were developed in coordination with the state agencies responsible for their development and implementation.

Policy Package 1: Trend Policy

The Trend policy package assumes very moderate, trend-based improvements in vehicle fuel economy, the carbon intensity of fuel, building energy and water efficiency, and the proportion of renewable power¹⁸ used by utilities in their power generation portfolio. This policy set is an important component of any business-as-usual future and serves as a comparison to a future in which more aggressive policies are adopted and achieved.

Policy Package 2: Green Policy

The Green policy package reflects the relatively aggressive direction of adopted state policies and those under consideration by the Air Resources Board (CARB), California Energy Commission (CEC), California Public Utilities Commission (CPUC), and other agencies. It includes leading-edge policies for vehicle fuel economy, the carbon intensity of fuel, building energy and water efficiency, and the proportion of renewable resources used by utilities in their power generation portfolio. This policy package, when combined with each of the three land use options, tests a future in which these aggressive policies are adopted and achieved.

The core components of each policy package are outlined in the table below. Details about the policy packages and how they are adjusted in the Rapid Fire model can be found in the *Rapid Fire Model White Paper and Technical Guide*.

	Policy Package 1: TREND POLICY			Policy Package 2: GREEN POLICY		
	2020	2035	2050	2020	2035	2050
Transportation						
Fuel economy	24 mpg gas eq. ^{i,ii,iii} <i>Meets Pavley I Clean Car Standard</i>	27 mpg	28 mpg	25 mpg	38 mpg	54 mpg <i>Meets Pavley I and II, with continued improvement after 2020</i>
Fuel price	\$4.00/gal ^{iv} <i>Reflects 2.4% annual increase in price</i>	\$5.50	\$8.00	\$4.00	\$5.50	\$8.00 <i>Reflects 2.4% annual increase in price</i>
Buildings						
Energy use of new buildings	10% below 2005 <i>Reflects modest efficiency improvements</i>	20%	30%	30%	55%	80% <i>Reflects strong policy for efficiency improvements</i>
Energy use of existing buildings	0.5% less per year <i>Reflects modest policy for building retrofits</i>	0.5%	0.5%	0.75%	1.25%	2% <i>Reflects strong policy for building retrofits</i>
Electricity price	\$0.17/kWh <i>Reflects increase related to moderate growth in renewables</i>	\$0.18	\$0.18	\$0.18	\$0.20	\$0.22 <i>Reflects increase related to high growth in renewables</i>
Natural gas price	\$1.71/therm <i>Reflects a trend-based 2% annual increase in price</i>	\$2.30	\$3.10	\$1.71	\$2.30	\$3.10 <i>Reflects a trend-based 2% annual increase in price</i>
Water use of new residential buildings	10% below 2005 <i>Reflects modest efficiency improvements</i>	20%	30%	30%	50%	70% <i>Reflects strong policy for efficiency improvements</i>
Water use of existing buildings	10% below 2005 <i>Reflects modest policy for building retrofits</i>	15%	20%	25%	35%	50% <i>Reflects strong policy for building retrofits</i>
Water price	\$1,050/AF <i>Reflects a 1.1% annual increase in price</i>	\$1,250	\$1,450	\$1,050	\$1,250	\$1,450 <i>Reflects a 1.1% annual increase in price</i>
Energy Emissions						
Transportation fuel emissions	17.7 lbs CO ₂ e/gal ge <i>Reaches Low Carbon Fuel Standard 10% reduction goal by 2020</i>	17.7 lbs	17.7 lbs	17.7 lbs	13.7 lbs	9.8 lbs <i>Reaches LCFS 10% goal by 2020, with continued improvement to 2050</i>
Electricity emissions	0.69 lbs/kWh <i>Reflects increase in renewables to 33% in 2050</i>	0.62 lbs	0.58 lbs	0.58 lbs	0.48 lbs	0.35 lbs <i>Reflects increase in renewables to 60% in 2050</i>
Natural gas emissions	11.7 lbs/therm <i>Reflects constant rate of on-site combustion emissions</i>	11.7 lbs	11.7 lbs	11.7 lbs	11.7 lbs	11.7 lbs <i>Reflects constant rate of on-site combustion emissions</i>

- Notes:
- i) Fuel economy and fuel emission rate projections are based on California's currently adopted vehicle and fuel standards (Pavley I Clean Car Standard and Low Carbon Fuel Standard).
 - ii) Values are rounded. For exact assumption values, refer to the Rapid Fire Model White Paper and Technical Guide.
 - iii) Throughout report, all fuel metrics are expressed in terms of gasoline equivalent (ge).
 - iv) All price assumptions are in 2008 dollars.

LAND CONSUMPTION and INFRASTRUCTURE

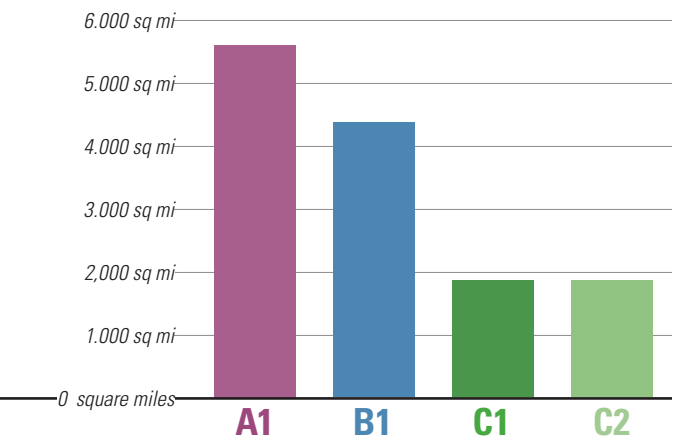
Land Consumption and Infrastructure Costs

Land Consumption

The amount of land consumed to accommodate new population growth varies substantially among the Rapid Fire scenarios. New land consumption includes all land that will be newly urbanized, including residential and employment areas, roadways, open space, and public lands. The Rapid Fire model estimates land consumption based on per-capita rates of land consumption by Land Development Category (Urban, Compact, and Standard).

Scenario A1, which accommodates 70% of growth through 2050 in the Standard LDC, consumes more than twice the land of Scenarios C1 and C2, which accommodate from 80% to 90% of new growth in the Compact and Urban LDCs. The 'C' Scenarios include a very low proportion of low-density greenfield growth, focusing instead on infill and redevelopment within existing urban areas and on more compact forms of new growth.

Cumulative New Land Consumption to 2050



Cumulative New Land Consumption

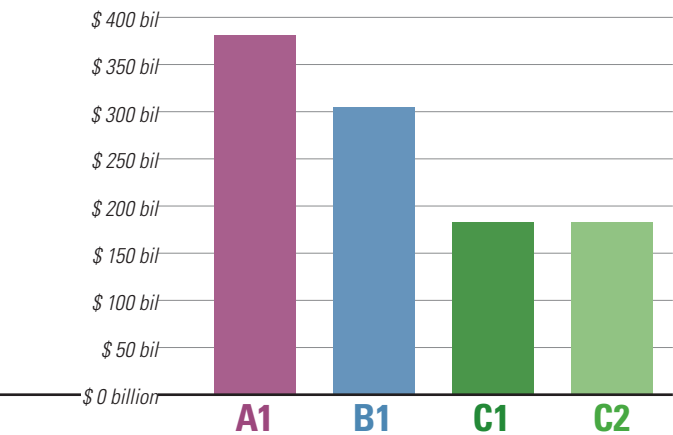
	2035	2050
A1 BUSINESS AS USUAL	3,700 sq mi	5,600 sq mi
B1 MIXED GROWTH	2,920 sq mi	4,370 sq mi
C1 GROWING SMART	1,390 sq mi	1,850 sq mi
C2 GREEN FUTURE	1,390 sq mi	1,850 sq mi

Infrastructure Cost

Increased land consumption leads to higher costs for local and sub-regional infrastructure, as new greenfield development requires significant capital investments in new local roads, water and sewer systems, and dry utilities (electricity, gas, phone, and cable). Conversely, growth focused in existing urban areas takes advantage of existing infrastructure and capitalizes on the efficiencies of providing service to higher concentrations of jobs and housing. When comparing Scenario A1 to Scenarios C1 and C2, local and sub-regional infrastructure cost savings add up to more than \$24,000 per new household by 2050 – a cumulative savings of more than \$65 billion through 2035, and \$194 billion through 2050.

While the Rapid Fire model does not yet analyze the costs for operations and maintenance, these cost differences are expected to widen as the cost of ongoing maintenance (most often borne by local and regional agencies and operations) is included in future versions of the model. Future versions will also account for the incremental cost of infill and greyfield development and thus produce a more complete picture of infrastructure cost variations among land use patterns.

Cumulative New Infrastructure Costs to 2050 (2008 dollars)



Cumulative New Infrastructure Costs

	2035	2050
A1 BUSINESS AS USUAL	\$249 bil	\$378 bil
B1 MIXED GROWTH	\$199 bil	\$302 bil
C1 GROWING SMART	\$121 bil	\$183 bil
C2 GREEN FUTURE	\$121 bil	\$183 bil

TRANSPORTATION

Vehicle Miles Traveled

Transportation system impacts – including vehicle miles traveled (VMT), fuel use and cost, and GHG and air pollutant emissions – vary significantly across the Rapid Fire scenarios. The different land use options result in different rates of passenger automobile use, measured as vehicle miles traveled, or VMT. The subsequent effect of VMT on fuel consumption, cost, and emissions are determined by specific policy-based assumptions about auto fuel economy and technology, and fuel composition and cost.¹⁹

Vehicles Miles Traveled (VMT)

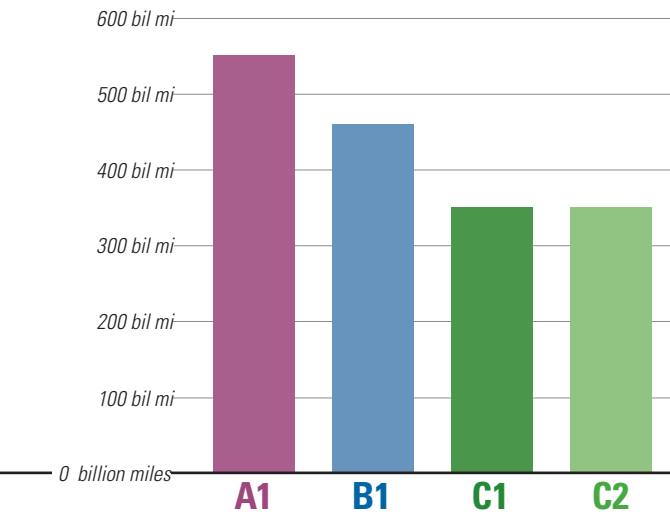
The Rapid Fire model calculates VMT by applying assumptions about per-capita annual VMT to population growth. These assumptions, which differ by Land Development Category, are based on research and empirical evidence that per-capita VMT of both incremental (new) population and base year (existing) population vary based on the form of new growth.²⁰ Moreover, this variation is expected to change over time as areas become either more urban or compact, or more sprawling (determined based on the proportions of LDCs in a scenario).

Variations in VMT across the scenarios is a result of year-by-year variation in per capita VMT by form of new growth (Urban, Compact, or Standard), and also the impact of new growth on the travel behavior of those already living in California in the base year (2005). For example, if one is living in an area 20 years from now that has seen increased transit service and/or new retail development in close proximity to their home or workplace, it is likely that they will drive less (and walk, bike, or take transit more) because daily destinations and services are closer.

It is an *a priori* assumption of the Rapid Fire model that requisite transportation investments go hand in hand with growth patterns, such that scenarios with a greater focus on Compact and Urban development would see increased transit, bicycle, pedestrian, streetscape, and livability investments. Conversely, scenarios dominated by Standard development would see large budget outlays to highway and road expansion.

Scenario results for VMT indicate a wide variation in passenger vehicle use related to the form of new growth. Scenario A1, which accommodates 70% of growth in auto-oriented Standard development, see much higher VMT rates than the B and C Scenarios. Total annual VMT in the C scenarios is 34% lower than that in Scenario A1 in 2050. Average per-capita passenger VMT in 2050 ranges from 9,050 in A1, to 7,850 in B1, to 5,970 in C1 and C2. Note that VMT is determined by the land use option in a scenario, and is independent of the policy packages selected; C1 and C2, with the same land use option, result in identical VMT estimates.

Total Annual Vehicle Miles Traveled in 2050



Annual VMT per Capita

	2005	2035	2050
A1 BUSINESS AS USUAL	8,100 mi	8,740 mi (+ 8%)	9,050 mi (+ 12%)
B1 MIXED GROWTH	8,100 mi	7,850 mi (- 3%)	7,850 mi (- 3%)
C1 GROWING SMART	8,100 mi	6,670 mi (- 18%)	5,970 mi (- 26%)
C2 GREEN FUTURE	8,100 mi	6,670 mi (- 18%)	5,970 mi (- 26%)

Pricing Effects

Fuel price, along with other driving costs, have both short- and long-term effects on driving decisions. Research into historic patterns has quantified relationships among the interrelated factors of VMT and automobile fuel economy with costs including fuel price, fuel taxes, automobile ownership, insurance, and maintenance costs, and parking, toll, and congestion charges. The results, expressed as an “elasticity” of change in one factor with respect to change in another, can be used to estimate the effects of specific policy- or program-based assumptions on VMT. Pricing elasticities have not been applied in calculating the results presented in this report; however, the Rapid Fire model does allow users to “turn on” sensitivity to changes in per-mile driving costs to estimate changes in VMT due to pricing.

TRANSPORTATION

Fuel Consumption and Driving Costs

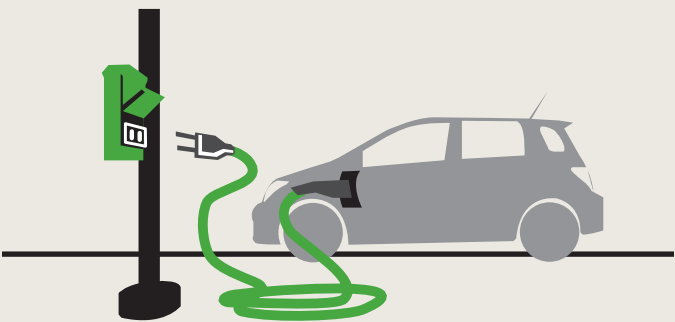
Automobile Fuel Use and Cost of Driving

Variations in passenger VMT lead to substantial differences in the amount of automobile fuel (gasoline equivalent) used in each of the scenarios. Scenarios A1, B1, and C1, which all include the same modest vehicle fuel economy assumption, show significant differences in fuel use due to land use-related VMT variations. When combined with policy variations for automobile efficiency and fuel cost, the scenarios illustrate the combined impact of land use and policy packages. Assuming the more aggressive efficiency standards of the “green” policy set brings auto fuel use in Scenario C2 down further: annual auto fuel use in 2050 is 66% lower in C2 than in Scenario A1. Between 2005 and 2050, the savings amount to nearly 260 billion gallons of fuel.

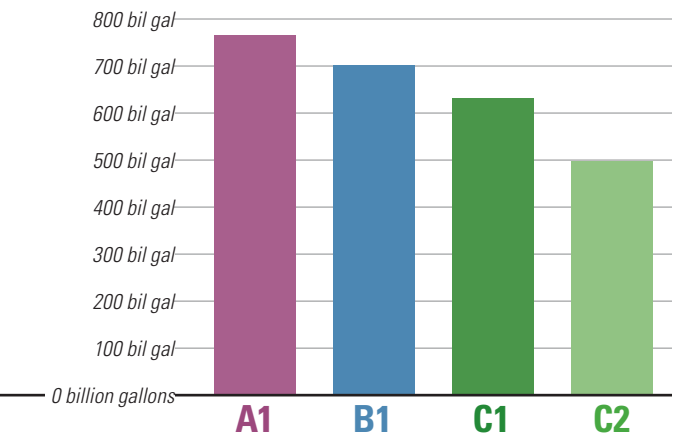
Reduced VMT and fuel use leads to lower costs for all households in California. When compared to Scenario A1, Scenario C2 saves the average California household more than \$8,600 per year in driving-related costs in 2050. Statewide, the savings total \$170 billion per year.

Alternative Vehicle Impacts

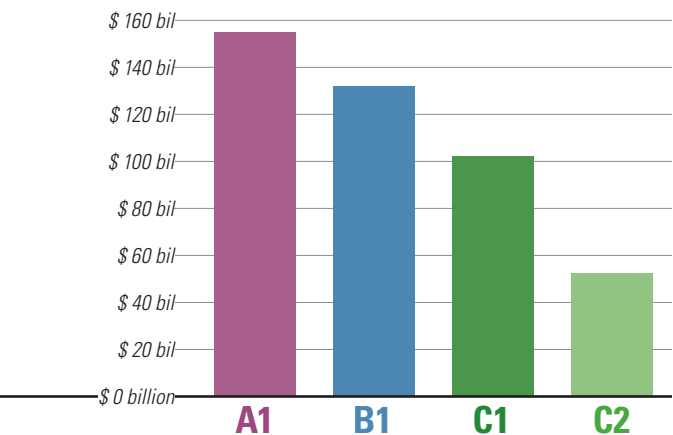
Electric and other alternative fuel vehicles play an important role in reducing GHG emissions from transportation. These Vision California model results implicitly capture the impacts of electric vehicle use because the fuel economy and GHG emission rate assumptions used in the Rapid Fire model are based on California’s adopted and/or proposed policies for improving vehicle fuel economy (California’s AB 1493 Clean Car Standards, or “Pavley I”, and the anticipated “Pavley II”) and decreasing fuel carbon intensity (Low-Carbon Fuel Standard) – each of which assumes that growing shares of electric and other alternative fuel vehicles in the on-road fleet are necessary to reach targets. Consistent with regulatory targets, all assumptions and results for fuel use, fuel economy, and fuel emissions in the Rapid Fire model are expressed in terms of gallons of gasoline equivalent.²¹



Cumulative Passenger Vehicle Fuel Consumption to 2050 (gallons gasoline equivalent)



Total Annual Fuel Costs in 2050 (2008 Dollars)



Annual Driving Costs per Household*

	2035	2050
A1 BUSINESS AS USUAL	\$14,600	\$18,000
B1 MIXED GROWTH	\$13,100	\$15,600
C1 GROWING SMART	\$11,100	\$11,800
C2 GREEN FUTURE	\$9,900	\$9,300

* Driving costs include fuel and auto ownership, maintenance, and insurance costs calculated on an average per-mile basis.

TRANSPORTATION

Greenhouse Gas and Air Pollutant Emissions

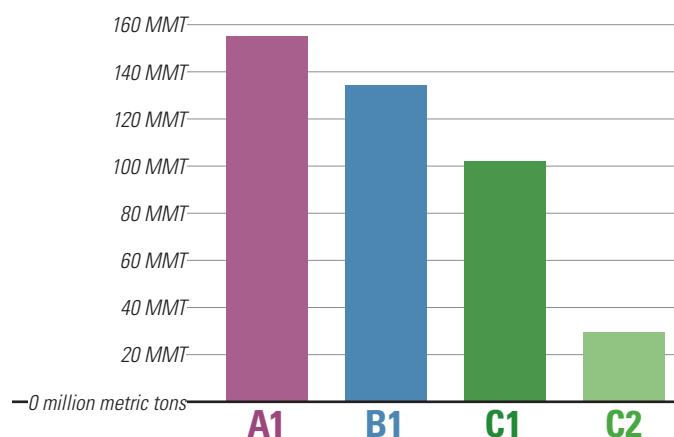
GHG Emissions from Passenger Vehicles

GHG emissions from passenger vehicles are determined by VMT (which is related to land use patterns), vehicle fuel economy, and the carbon intensity of automobile fuel. Scenarios A1, B1, and C1, with the same Trend-based policy set, reveal the emissions differences among land use options. Scenario C2 demonstrates the additional impact of adding the Green policy package to a Smart Growth future.

Scenario C1 highlights the significant impact of land use on vehicle GHG emissions, with 2050 emissions that are 34% lower than those of Scenario A1. With its combination of more compact and urban land uses and advanced vehicle and fuel policies, GHG emissions in Scenario C2 are fully 80% lower than those of A1. The results across all scenarios highlight the need to seek reductions through both compact land patterns and progressively stronger vehicle and fuel policies to 2050.

Note that, to remain consistent with the GHG target-setting process under SB 375, the transportation emissions reported here are limited to tailpipe (tank-to-wheel) emissions. A more complete picture of emissions emerges in an analysis of full lifecycle (well-to-wheel) emissions. The Rapid Fire model estimates both combustion and lifecycle emissions.

Total Annual Transportation GHG Emissions in 2050 (MMT CO₂e)



Annual Transportation CO₂e Emissions per Capita (lbs CO₂e)

	2005	2035	2050
A1 BUSINESS AS USUAL	8,500 lbs	5,720 lbs (- 33%)	5,730 lbs (- 33%)
B1 MIXED GROWTH	8,500 lbs	5,130 lbs (- 40%)	4,970 lbs (- 42%)
C1 GROWING SMART	8,500 lbs	4,360 lbs (- 49%)	3,780 lbs (- 56%)
C2 GREEN FUTURE	8,500 lbs	2,390 lbs (- 72%)	1,080 lbs (- 87%)

Air Pollutant Emissions from Passenger Vehicles

Differences in VMT lead to different levels of air pollutants (including nitrogen oxides, carbon monoxide, sulfur dioxide, volatile organic compounds, and particulate matter) among the Rapid Fire scenarios. With higher VMT, Scenario A1 sees 2035 passenger-vehicle pollutant emissions that are 27% higher than emissions in Scenario C2. By 2050, changes in vehicles and fuels are expected to dramatically reduce emissions per mile.

Total Annual Air Pollutant Emissions

	2005	2035	2050*
A1 BUSINESS AS USUAL	2,525,200 tons	557,950 tons	29 tons
B1 MIXED GROWTH	2,525,200 tons	500,900 tons	25 tons
C1 GROWING SMART	2,525,200 tons	425,760 tons	19 tons
C2 GREEN FUTURE	2,525,200 tons	425,760 tons	19 tons

* Air pollutant emission rate assumptions are based on statewide EMFAC projections to 2040, and extrapolated to 2050. By 2040, EMFAC's per-mile air pollutant emission rates approach zero.

RESIDENTIAL and COMMERCIAL BUILDING ENERGY

Energy Consumption, Cost, and Greenhouse Gas Emissions

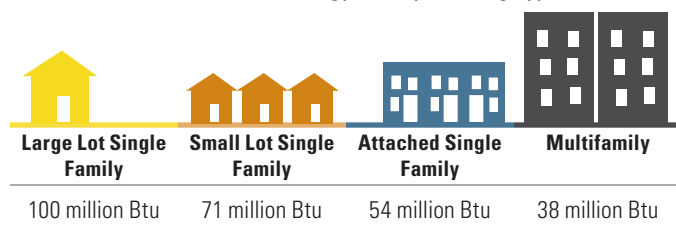
The Vision California Rapid Fire scenarios vary in their residential and commercial energy use profiles due to their building program and policy assumptions. Scenarios B1, C1, and C2, which include a larger proportion of Compact and Urban development, accommodate a higher proportion of growth in more energy-efficient housing types like townhomes, apartments, and smaller-lot single family homes, and more compact commercial building types. By contrast, the large proportion of Standard development in Scenario A1 leads to a higher proportion of large-lot single family housing, which is typically less energy-efficient due to their larger sizes. When combined with the effects of more stringent building efficiency and clean energy policies, how each scenario accommodates growth has a very significant impact on resource consumption, cost, and GHG emissions.

Energy Consumption, Cost, and Emissions

The Rapid Fire model calculates building energy use for the base/existing population (residential and commercial buildings already built by the 2005 baseline year) and for the growth increment (new buildings built during the time span of the model). To estimate energy use for base/existing buildings, the model assumes rates of building retrofits, upgrades, and replacement. For new buildings, the model assumes that, year-upon-year, new construction will be built to meet higher efficiency standards. Energy use varies by building type, and according to changing policies for building efficiency.

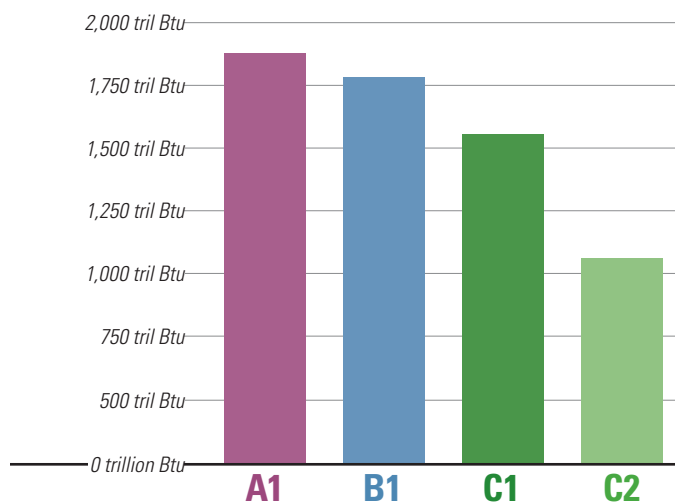
The smart land use of Scenario C1 brings energy use in 2050 to 15% lower than that of Scenario A1, which has the same policy assumptions but a more sprawling, trend-based land pattern. Applying Green building and energy policies in Scenario C2 increases this annual difference to 43%. The cumulative residential cost savings to 2050 amount to more than \$225 billion, or approximately \$6.4 billion per year in 2035, and \$15 billion in 2050. Greenhouse gas emissions generally track energy use, with the most substantial reductions seen in scenarios that combine smarter land patterns and green building and energy policies.

Baseline Annual Household Energy Use by Building Type*



* Includes residential electricity and natural gas use. Statewide baseline average consumption data derived from California Energy Commission Statewide Residential Appliance Saturation Survey (RASS), 2004.

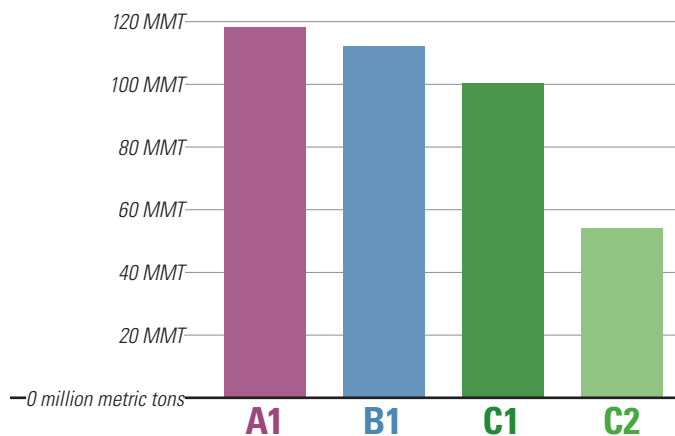
Annual Residential and Commercial Building Energy Use in 2050 (Btu)



Annual Residential Energy Consumption per Household

	2035	2050
A1 BUSINESS AS USUAL	60 mil Btu	57 mil Btu
B1 MIXED GROWTH	58 mil Btu	55 mil Btu
C1 GROWING SMART	55 mil Btu	50 mil Btu
C2 GREEN FUTURE	45 mil Btu	34 mil Btu

Total Annual Residential and Commercial Building Energy CO₂e Emissions in 2050 (MMT CO₂e)



Annual Residential Building Energy Emissions per Household

	2035	2050
A1 BUSINESS AS USUAL	8,400 lbs	7,700 lbs
B1 MIXED GROWTH	8,150 lbs	7,400 lbs
C1 GROWING SMART	7,700 lbs	6,850 lbs
C2 GREEN FUTURE	5,700 lbs	3,850 lbs

RESIDENTIAL WATER

Water Consumption, Costs, and Greenhouse Gas Emissions

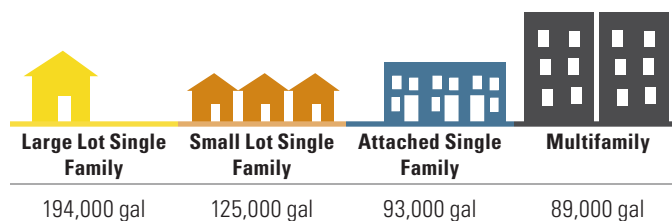
The building program and policy variations among the Vision California Rapid Fire scenarios lead to significant differences in water use and cost. Residential water use is a function of both indoor and outdoor water needs, with outdoor use (landscape irrigation) accounting for the majority of the difference among housing types. Because homes with larger yards require more water for landscape irrigation, lot size is generally correlated with a household's overall water consumption. Thus, scenarios with a greater proportion of the Standard Land Development Category, which includes primarily large-lot single-family homes, require more water than scenarios with a greater proportion of Compact or Urban areas, which include more attached and multifamily homes.

Residential water use in Scenario C1, with smart land use and trend policies, is almost 10% lower than that of A1, with its more dispersed land pattern. Residential water use in Scenario C2, with both smart land use and green policies, is over 40% lower than that of A1. The difference in cumulative water use between A1 and C2 amounts to nearly 78 million acre feet by 2050. The average household uses 40,000 gallons less per year by 2035, and 55,000 gallons less per year by 2050. Cumulative cost savings to 2050 amount to more than \$96 billion. Total water use in Scenario C2 costs \$2.5 billion less per year in 2035, and \$5 billion less in 2050.

GHG Emissions from Water-Related Energy Use

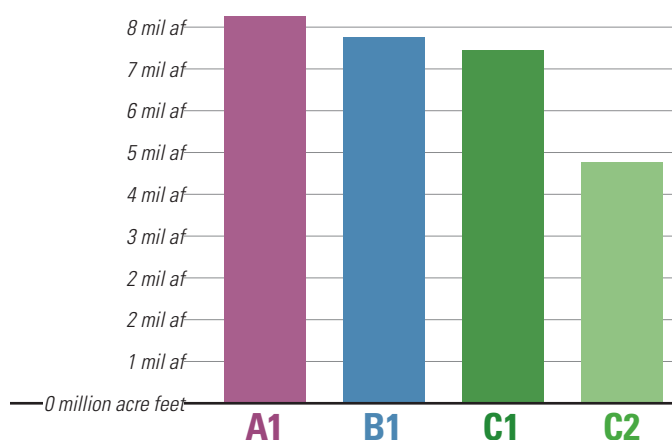
Water-related GHG emissions result from two main categories of energy use: a) system uses, including the transport, treatment, and distribution of water consumed; and b) end uses, including all uses of water that occur within homes (e.g., water heating).²² The Rapid Fire model calculates energy use and emissions for system uses, while emissions resulting from end uses are accounted for as a component of residential and commercial building energy emissions. Water-related GHG emissions vary across the Vision California Rapid Fire scenarios with changes in water energy use and the rate of GHG emissions from electricity. Total emissions for Scenario C1 are 10% lower than A1 in 2050; with the Green policy package of Scenario C2, the difference grows to 64%. Scenarios A1 and C1 have the same policy set and thus highlight the impact of land use patterns and building program on this component of GHG emissions.

2005 Annual Household Water Use by Building Type*



* Statewide baseline average consumption figures include indoor and outdoor water use. Indoor use is based on per-capita averages; outdoor use is based on generalized assumptions about landscape area and irrigation requirements.

Total Annual Residential Water Use in 2050



Annual Residential Water Use per Household

	2035	2050
A1 BUSINESS AS USUAL	141,500 gal	133,600 gal
B1 MIXED GROWTH	137,850 gal	129,050 gal
C1 GROWING SMART	131,450 gal	120,400 gal
C2 GREEN FUTURE	101,150 gal	78,150 gal

Annual Water-Related Emissions for Residential Water Use (MMT CO₂e)

	2035	2050
A1 BUSINESS AS USUAL	5.7 MMT	5.8 MMT
B1 MIXED GROWTH	5.6 MMT	5.6 MMT
C1 GROWING SMART	5.3 MMT	5.2 MMT
C2 GREEN FUTURE	3.1 MMT	2.1 MMT

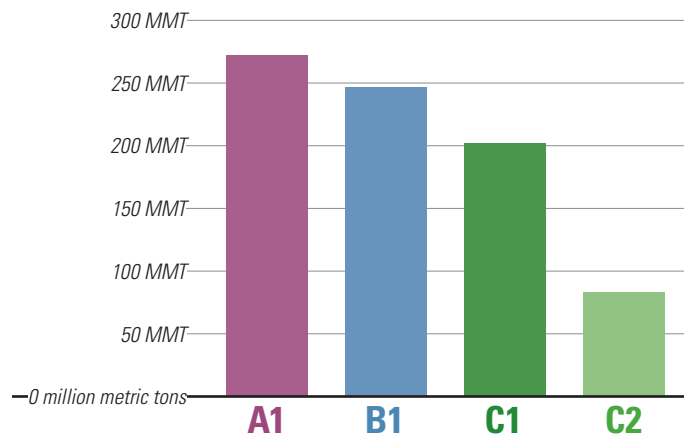
GREENHOUSE GAS EMISSIONS SUMMARY

Combined transportation and building sector impacts provide the most complete picture of the greenhouse gas emissions and fiscal implications of the futures presented by the Vision California Rapid Fire scenarios. Passenger vehicle transportation, along with residential and commercial building energy use, currently account for over half of total carbon emissions in California. Emissions and costs vary significantly across the four scenarios, highlighting the importance of both land use patterns and policies regulating energy emissions and efficiency on California's greenhouse gas emission reductions goals and financial health.

Greenhouse Gas Emissions from Transportation and Buildings

Total GHG emissions – including those from passenger vehicles, and emissions associated with residential and commercial building energy consumption – vary greatly across scenarios due to differences in land use and policy. Scenario A1, with its business-as-usual land use pattern and policy set, sees the highest total GHGs from both buildings and transportation through all horizon years. Scenarios B1 and C1, with the same trend policy set, highlight the impact of land use patterns in total greenhouse gas emissions from buildings and transportation. Scenario C1, with its more efficient land use pattern, produces significantly fewer GHG emissions than A1 or B1. Scenario C2, which combines the efficient land use pattern with green policies, is able to further reduce total GHG emissions.

Total Annual Transportation and Building Energy GHG Emissions in 2050 (MMT CO_{2e})



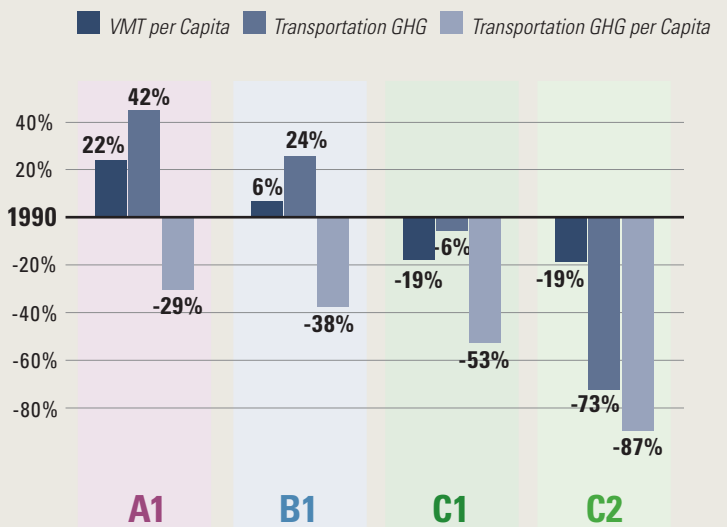
Total Annual GHG Emissions from Transportation and Buildings (MMT CO_{2e})

	2005	2035	2050
A1 BUSINESS AS USUAL	247 MMT	248 MMT (0.6%)	272 MMT (10%)
B1 MIXED GROWTH	247 MMT	230 MMT (-7%)	246 MMT (-0.4%)
C1 GROWING SMART	247 MMT	204 MMT (-17%)	202 MMT (-18%)
C2 GREEN FUTURE	247 MMT	129 MMT (-48%)	83 MMT (-66%)

From VMT to GHG

As demonstrated by the results of the Rapid Fire statewide scenarios, land use planning and policy act in conjunction to reduce emissions to meet our state goals. The chart at right shows the relative change in per-capita VMT from 1990 to 2050 alongside changes in total and per-capita GHG emissions. The results across the four scenarios illustrate both the separate and combined impacts of land use (affecting VMT) and auto and fuel policies (affecting fuel use and amount of GHG emissions per gallon). Only Scenario C2, which combines smart land use with progressive policies for vehicle technology and fuel composition, comes close to achieving the target 80% reduction in total transportation GHG emissions from 1990 levels by 2050.

VMT per Capita and Total per Capita Transportation GHG Emissions, 2050 vs. 1990



COST SUMMARY

Household Expenditures and Infrastructure Costs

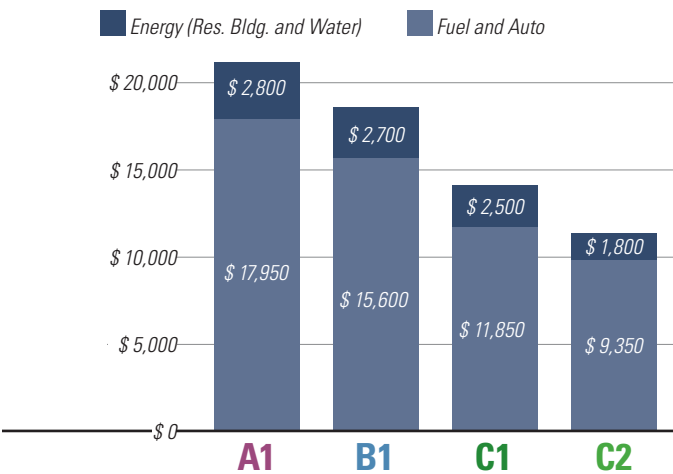
The total cost burden for the four Vision California Rapid Fire scenarios varies along with the resource consumption of each of the scenarios. Infrastructure capital costs, as well as household transportation, energy, and water costs, are much higher in scenarios with more land consumption, higher automobile vehicle miles traveled (VMT), and building programs that rely more on larger lot single family construction. Thus, Scenario A1 exhibits higher total costs than the other scenarios. Comparing the three scenarios with the same Trend policy set isolates the impact of land use on total cost; Scenario C1, with the lowest land consumption and VMT, and the most resource-efficient building program, saves more than \$1 trillion by 2035 over Scenario A1, and more than \$2.6 trillion by 2050. Adding the Green policies in Scenario C2 extends these savings to more than \$1.3 trillion by 2035 and more than \$3.7 trillion by 2050.

Average Annual Household Expenditures:
Fuel and Auto Costs, Residential Electricity, Gas, and Water

	2035	2050
A1 BUSINESS AS USUAL	\$17,100	\$20,750
B1 MIXED GROWTH	\$15,550	\$18,300
C1 GROWING SMART	\$13,450	\$14,350
C2 GREEN FUTURE	\$12,000	\$11,150

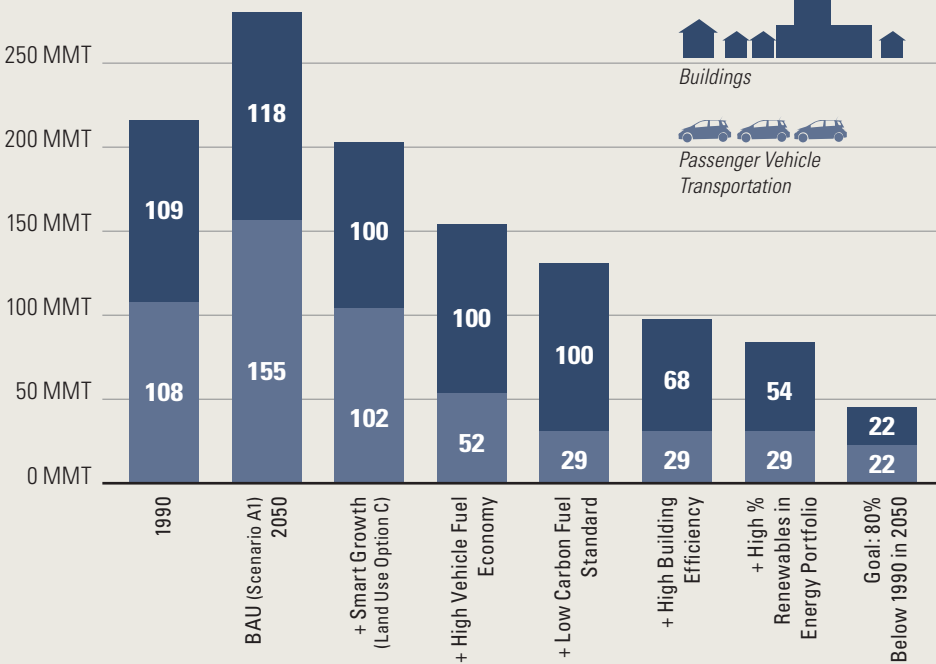
Breaking costs down to the household level exposes the impact of land use and policy choices on California households. In 2050, households in Scenario C2 save an average of \$9,600 per year (compared to Scenario A1) in costs associated with driving and residential energy and water use. This difference is further exacerbated by the addition of local infrastructure cost burdens, which are typically passed on to homeowners and renters in the form of taxes, fees, home prices, and assessments. The difference between Scenarios A1 and C1, both with the same Trend policy set but varying land patterns, leads to a total savings of over \$145,000 from 2005-2050 for each household in California. The Green policies in Scenario C2 extend this savings to more than \$200,000 per household from 2005-2050.

Total Costs per Household (2008 dollars)



Meeting California's Climate, Energy, Resource, and Fiscal Challenges

The chart at right summarizes how land use and specific "green" policy options contribute to GHG emission savings in California by 2050. The bottom set of bars represents emissions from passenger vehicle transportation, while the top set represents emissions from residential and commercial energy use. Moving from left to right, each column applies one additional land use change or policy based on the scenario options outlined in this report. Overall, the results make it evident that meeting AB 32's goal of reducing GHG emissions to 80% below 1990 requires comprehensive and progressive land use action, as well as policy moves across multiple sectors and agencies throughout the state.



ENDNOTES and REFERENCES

Endnotes

1. For copies of the *Rapid Fire White Paper and Technical Guide*, please contact Calthorpe Associates directly at: VisionCalifornia@calthorpe.com.
2. The developed footprint has been growing at a rate of roughly 1.6% per year annually since 1980, a rate of land development that has outpaced population growth by 25% (Theobald, 2005).
3. The UC Davis Institute of Transportation Studies estimates that, under current trends, VMT per capita will increase to 9,975 by the year 2050 (Yang, McCollum, McCarthy, & Leighty, 2008).
4. Caltrans estimates that VMT will continue to increase at nearly 3 percent per year for the foreseeable future under current trends (Bartholomy, et al., 2007).
5. Between 1998 and 2004, approximately 83% of new construction in major metropolitan areas was made up of single family detached homes. (ULI, 2009)
6. According to a 2009 article in the Sacramento Bee quoting SACOG Executive Director Michael McKeever, "60 percent to 70 percent of recent new housing across the region and much now in the pipeline is on 'small lots' of 5,000 square feet or less, or is attached, as in condominiums and townhouses." (Wasserman, 2009).
7. (ULI, 2003)
8. (ULI, 2009)
9. (Levine, Frank, & Chapman, 2004)
10. (U.S. Census Bureau, 2005)
11. (ULI, 2003)
12. (Nelson, 2006)
13. According to the study (U.S. Environmental Protection Agency, 2010), there has been an acceleration of residential construction in existing urban neighborhoods, reflecting a fundamental shift in the real estate market that is driven by lower crime rates in central cities, changing demographics, increased demand for homes in walkable communities, closer proximity to high-paying jobs, rising energy costs, pedestrian access to amenities (retail, restaurants, parks, supermarkets, etc.), and transit-oriented development.
14. (ULI, 2009)
15. From the New York Times: "Homes beyond the urban core have been falling in value faster than those within" (Goodman, 2008); "the further you get from the city, the more prices have declined" (Bajaj, 2009).
16. Includes all units (including townhouses) on lots under $\frac{1}{8}$ acre and half the units on lots between $\frac{1}{8}$ and $\frac{1}{4}$ acre. (Nelson, 2006)
17. Includes all units on lots over $\frac{1}{6}$ acre. (Nelson, 2006)
18. Within the context of this report, "renewable energy" refers to any utility power generation technology that does not directly produce greenhouse gases. Hydroelectric, solar, wind, wave, nuclear energy are all thus defined as "renewable," while energy from natural gas, oil, and coal are not.
19. Baseline 2005 statewide fleet efficiency for California was calculated using the CARB Emissions Factors (EMFAC 2007) model. EMFAC vehicle classes included in the LDV fleet: light-duty automobiles (LDA), light-duty trucks up to 5750 lbs (LDT1 and LDT2), and medium-duty trucks up to 8500 lbs (MDV).
20. For a thorough description of the Rapid Fire VMT modeling methodology, including an analysis of VMT in sample LDC areas and a discussion of relevant studies, please refer to the *Rapid Fire White Paper and Technical Guide*.
21. Note that the Rapid Fire model gives users the option to separately estimate the dedicated impacts of electric vehicles and standard internal combustion engine (ICE) vehicles. Electricity demand and emissions estimates are calculated based on assumptions about the proportion of electric vehicles in the on-road fleet, and their average fuel economy. These assumptions may be guided by ongoing studies by the California Energy Commission and California Air Resources Board.
22. In California, 19% of all electricity and 30 percent of natural gas are associated with urban and agricultural water use; of this, 73% of the electricity and nearly all of the natural gas are associated with end uses. These energy uses are estimated to account for at least 44 MMT CO₂ average annual emissions (DWR 2009, CEC 2006).

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BACKGROUND

Rapid Fire Model Output Metrics and Input Assumptions

Summary of Output Metrics

Land Consumption <ul style="list-style-type: none"> Land Consumed (square miles) 	Infrastructure Cost <ul style="list-style-type: none"> Cost for roads and wet and dry utilities provision (\$)
Transportation System Impacts and Emissions <ul style="list-style-type: none"> Vehicle Miles Traveled (VMT) (miles) Fuel Consumed (gal) Fuel Cost (\$) Transportation Electricity Consumed (kWh) Transportation Electricity Cost (\$) Transportation Electricity CO₂e Emissions (MMT) ICE Fuel Combustion CO₂e Emissions (MMT) ICE Full Fuel Lifecycle CO₂e Emissions (MMT)* Criteria Pollutant Emissions (tons) 	Building Energy, Cost, and Emissions <ul style="list-style-type: none"> Residential Energy Consumed (Btu) Commercial Energy Consumed (Btu) Total Energy Consumed (Btu) Residential Building CO₂e Emissions (MMT) Commercial Building CO₂e Emissions (MMT) Residential Energy Cost (\$) Building Water Use, Cost, and Emissions Water Consumed (AF) Water Cost (\$) Water-Related Electricity Use (GWh) Water-Related Electricity CO₂e Emissions (MMT)
Total Greenhouse Gas (GHG) Emissions <ul style="list-style-type: none"> Total CO₂e Emissions (Transportation & Buildings, MMT) 	Building Program <ul style="list-style-type: none"> Housing type mix

* Denotes an optional output not generated for the scenarios presented in this report.

Summary of Input Assumptions

Demographics <ul style="list-style-type: none"> Baseline population and population growth Baseline households and household growth Baseline housing units and housing unit growth Baseline non-farm jobs and job growth 	Scenarios <ul style="list-style-type: none"> Land Development Category (LDC) proportions for each scenario and time period Housing unit composition for each LDC
Infrastructure Cost <ul style="list-style-type: none"> Cost inputs for roads and wet and dry utilities provision by Land Use Category 	Land Consumption <ul style="list-style-type: none"> Percent greenfield vs. infill/greyfield/brownfield growth for each land development category, scenario, and time period Acres per capita required for greenfield development in each land development category, scenario, and time period
Vehicle Miles Traveled (VMT) <ul style="list-style-type: none"> Baseline Per Capita Light Duty Vehicle (LDV) VMT VMT adjustment factors by LDC and scenario for growth increment population VMT escalation and deceleration rates for the baseline environment population Elasticity of VMT with respect to driving costs per mile* 	Vehicle Fuel Economy and Cost <ul style="list-style-type: none"> Baseline fuel economy for total fleet, internal combustion engine vehicles alone*, and alternative/electric vehicles alone* Fuel economy in horizon years for total fleet, internal combustion engine vehicles alone*, and alternative/electric vehicles alone* Elasticity of fuel economy with respect to fuel cost*

* Denotes an optional input which was not applied in calculating the output metrics presented in this report.

<p>Transportation Emissions</p> <ul style="list-style-type: none"> • Baseline fuel emissions, full lifecycle (well-to-wheel) for total fleet, internal combustion engine vehicles alone*, and alternative/ electric vehicles alone* • Baseline fuel emissions, combustion (tank-to-wheel) for total fleet, internal combustion engine vehicles alone*, and alternative/ electric vehicles alone* • Percent gasoline vs. diesel in liquid fuel mix • Composition of gasoline and diesel fuel mix • Criteria pollutant emissions per mile traveled 	<p>Building Energy Emissions</p> <ul style="list-style-type: none"> • Electricity generation emissions (lbs/kWh) • Natural gas combustion emissions (lbs/therm) • Electricity generation emissions in horizon years (lbs/kWh) • Natural gas combustion emissions in horizon years (lbs/therm)
<p>Residential Building Energy Use & Price</p> <ul style="list-style-type: none"> • Baseline average annual energy use per unit for base/existing population • Annual energy use by building type • Housing unit replacement rate for base/existing housing stock • Upgrade efficiency reduction factor 'A' for base/existing housing stock • New efficiency reduction factor 'B' for replacement units of base/ existing housing stock • Upgrade efficiency reduction factor 'C' for replacement units of base/existing housing stock • New efficiency factor 'D' for new units of the growth increment • Upgrade efficiency factor 'E' for new units of the growth increment • Baseline residential electricity price • Baseline residential gas price • Residential electricity price in horizon years • Residential gas price in horizon years 	<p>Commercial Building Energy Use & Price</p> <ul style="list-style-type: none"> • Non-farm job proportion by floorspace-type category • Floorspace per employee by category for each LDC • Commercial space replacement rate for base/existing housing stock • Baseline average annual energy use per square foot for base/ existing commercial space • Annual baseline energy use for new commercial space • Replacement rate for base/existing commercial space • Upgrade efficiency reduction factor for base/existing commercial space • New efficiency reduction factor for replacement commercial space • Upgrade efficiency reduction factor for replacement commercial space • New efficiency factor for new floorspace of the growth increment • Upgrade efficiency factor for new floorspace of the growth increment • Baseline commercial electricity price • Baseline commercial gas price • Commercial electricity and gas price in horizon years
<p>Residential Building Water Use</p> <ul style="list-style-type: none"> • Baseline per capita indoor water demand by building type • Baseline per-unit outdoor water demand by building type • New residential water efficiency (% reduction from 2005) • Baseline water price (\$/acre foot) • Water price in horizon years (\$/acre foot) 	<p>Residential Water-Related Energy Use and Emissions</p> <ul style="list-style-type: none"> • Average water energy proxy (electricity required per million gallons water used)

* Denotes an optional input which was not applied in calculating the output metrics presented in this report.